



05-25-00

B0843-991160



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Patricia K. Parry 5/23/00
Patricia K. Parry

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

* * *

TRANSMITTAL OF PATENT APPLICATION

BOX PATENT APPLICATION

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Transmitted herewith for filing is the patent application for an invention entitled:

**TELESCOPE MIRROR FOR HIGH BANDWIDTH FREE SPACE
OPTICAL DATA TRANSMISSION**

Attorney Docket No.: B0843-991160
and invented by: Arnoldo Valenzuela, Giuseppe Valsecchi, Robert David
Banham and Fabio Marioni; and

claiming priority to European Application No. 00109448.1 filed May 3, 2000.

Enclosed are:

- 1) 9 pages of Specification; 4 pages of Claims; 1 page of Abstract;
and 1 page of List of Reference Numerals;
- 2) 4 sheets of Informal Drawings;
- 3) Unexecuted Declaration and Power of Attorney;
- 4) Check No. 443703 for \$1,026.00;
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Basic Filing Fee	XX	XX	\$690.00	\$345.00	\$ 690.00
Total Claims	30 - 20 =	10	X \$ 18.00	XS 9.00	\$ 180.00
Independent Claims	5 - 3 =	2	X \$ 78.00	X \$ 39.00	\$ 156.00
Multiple Dependent Claim(s) (if applicable)			\$ 260.00	\$130.00	\$ 0.00
Assignment Recordation Fee					\$ 0.00
Total of above Calculations =					\$ 1,026.00

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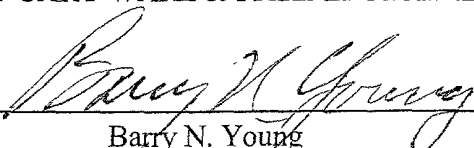
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Respectfully submitted,

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Telescope mirror for high bandwidth free space optical data transmission

The present invention relates to the use and manufacturing process of telescope mirrors for high bandwidth free space optical data transmission.

The increased need for high bandwidth (high data rate) communication links induced by the recent growth of the internet and other telecommunication means lead to renowned interest in the free space optical data transmission (Whipple, "Free space communications connects", Photonics at work, October 1999). In free space optical communications the data are transmitted through a communication link between a transmitting station to a receiving station by a laser being preferably having a frequency of about 1550 nm without using a physical medium like an optical fibre or the like. Depending on the weather conditions communication links over a distance of several kilometres with a bandwidth of up to 2.5 Gb/s have been demonstrated (P. F. Szajowski et al, "Key elements of high-speed WDM terrestrial free-space optical communications systems", SPIE Paper No. 3932-01). Such free space optical telecommunication links are especially useful for connecting facilities having high data transmission needs like banks or universities in metropolitan areas with one another. Another possible application is the live and high bandwidth broadcasting of sports events, where an optical free space communication link can be set up temporally with low costs.

In order to avoid health risks by the laser radiation the laser power has to be low (a few milliwatts) and the beam diameter must be large, about several 10 centimetres. To establish an optical free space communication link the optical signal therefor has to be coupled out of an optic fibre network and directed with a transmission telescope over the desired distance directly to the receiving telescope where the received beam has to be concentrated and coupled into an optical fibre network. The reliability and the achievable free space distances depend on the efficiency of the transmitter as well as the receiver telescopes. It is known to use high precision glass or zerodur mirrors as reflective optical elements of the transmitter as well as

There is therefore a need for cheap, reliable high precision optical elements for free space optical data transmission.

It is therefore an object of the present invention to provide an optical element suitable for high bandwidth free space optical communication which can be manufactured with high precision at moderate costs.

The problem is solved by a method of manufacturing a telescope mirror comprising the steps of: (a) providing a mandrel defining the geometry of the telescope mirror, (b) depositing a reflective layer on the mandrel surface, (c) electroforming a mirror body onto the reflective layer by an electrochemical process, (d) releasing the mirror body with the reflective layer from the mandrel, wherein the electroforming process and the release process are controlled such that the building up of internal mechanical tension within the mirror body is suppressed.

Furthermore, the method according to the invention allows the production of the optical (infrared) reflective layer having very low surface roughness. The reason is that the optical surface is not, like with conventional deposition technique, the deposition side surface having an unavoidable roughness but the opposite side surface of the reflective layer having formed an interface to the smoothened and polished mandrel surface.

In order to achieve a high surface and the geometry accuracy the deposition of the reflective layer is preferably carried out in a vacuum or electrochemical environment and the release step is carried out in clean room conditions. The release step is also optimized to avoid internal mechanical tension of the telescope mirror impairing geometry accuracy. Therefore, the release process must be performed uniformly over the whole geometry and a sticking of mirror shell portions to the mandrel must carefully be avoided.

The mirror body can be electroformed using nickel or a nickel alloy. Other suitable materials, however, may also be used.

The electroforming is preferably carried out using an electrochemical liquid having a temperature of between 40 °C and 70 °C.

For manufacturing a thin and/or large mirror a supporting structure may be attached to the mirror body. The attachment or combining step may be carried out before or after releasing the mirror body from the mandrel. In order to avoid the building up of internal mechanical stress within the mirror body an attaching step is preferably carried out under temperature conditions similar to the operating temperature of the finished telescope mirror.

The present invention further provides a transceiver device for high bandwidth free space optical data transmission comprising at least one reflector element having: a reflector body formed by an electrochemical replication technique using a mandrel defining the geometry of the reflector element, and a thin reflective layer on the reflector body.

In order to achieve high optical performance the deviation of a reflector element geometry from the designed geometry is preferably smaller than 50 µm. Deviations even smaller than 1 µm, however, are also achievable with the present invention.

The reflector elements according to the present invention may have a wide range of different thicknesses. For thinner reflector elements a supporting structure may be used. It is also possible to employ a supporting structure including actuators for adapting and correcting the geometry of the reflector element.

The present invention solves the above cited object furthermore with the use of reflector elements formed by an electrochemical replication technique using a mandrel defining the geometry of the reflector element as optical mirrors for high bandwidth free space optical data transmission.

The dependent claims describe further preferred features of the present invention.

Figure 1 is a schematic illustration of a high bandwidth free space optical communication link according to the present invention;

Figure 2b is a plan view of the backside of the optical telescope of Figure 2a;

Figures 3a through 3f show method steps of a mirror manufacturing process according to the present invention; and

Figure 1 is a schematical illustration of a free space optical communication link according to the present invention. A transmitter station (left side) and a receiving

station (right side) each comprising an optical fibre network are connected by a free space communication link between transceivers 20 preferably using infrared light having a wavelength of about 1550 nm. The optical signal is coupled from the optical fibre network 30 through the optical fibre terminal 31 into the transceiver 20 comprising a primary mirror 21 and a secondary mirror 22. The optical signal is then transformed into a parallel light beam having diameter of several ten centimetres. This large diameter is necessary in order to avoid potentially hazardous light intensities. The parallel light beam is then received by the receiving telescope 20 (in Figure 1 on the right hand side). It is obvious that the transmission efficiency and so the maximum possible distance depends on an exactly parallel light beam. This can only be achieved if the mirrors 21, 22 only minimally deviate from the designed geometry. This exact geometry is on the other hand also necessary on the receiving side for achieving a high concentrator efficiency into the optical fibre network. With highly precise telescope mirrors according to the invention an optical telecommunication link having a high efficiency and performance can therefore be realized.

Figure 2a shows a preferred embodiment of an optical telescope mirror according to the present invention. As shown in Figure 1 the telescope mirror comprises a primary mirror 21 and a secondary mirror 22 being exactly positioned to transform a small diameter light beam falling through an aperture 29 into a parallel light beam. The primary mirror 21 is supported by a supporting ring 23a to stabilize the mirror geometry under the influence of gravity. In the shown embodiment the supporting structure 23a has the form of a ring as is best seen in Figure 2b. Any other suitable geometry, however, is also conceivable.

Figure 2c shows another embodiment of the mirror 21 according to the invention having a supporting structure comprising actuators 23b connected by supporting elements 23c. With the actuators 23b the geometry of the mirror 21 can be adapted and corrected. As actuators 23b piezoelectric elements or electromagnetic elements having a high accuracy and short response time may be employed.

Figure 3 schematically shows method steps for manufacturing an optical mirror or reflector element according to the present invention. In the method step a) a mandrel 10 fixed on a rotatable shaft 11 is machined using a suitable machining tool 12. In step b) the mandrel or masterpiece 10 is polished with a suitable polishing tool 13. Method steps a) and b) are known in the art of producing optical mirrors. To achieve a high geometrical accuracy and surface smoothness these method steps have to be carried out very carefully by skilled and experienced technicians. The manufacturing of a precise mandrel 10 is therefore time consuming and costly. As material for the mandrel glass, zerodur Polymethylmetacrylat (PMMA), composite material, and metal may be used.

Then, in method step c) mandrel 10 has to be cleaned in order to remove chemical contamination, dust and particles from the surface. In method step d) a reflective layer is deposited onto the curved surface of the mandrel, for example by evaporating or sputtering gold from a gold source 15. Other coating materials instead of high purity gold may also be employed. The reflective layer material may be optimized to ensure a maximum reflectivity in the desired operational wavelength range. The reflective layer indicated by reference numeral 26 (Figure 4) has preferably a thickness of several ten nanometers to several hundred nanometers.

The process is continued with method step e) in which the mirror or reflector body 25 (Figure 4) is made by electroforming. Electroforming facility 16 is filled with an electrochemical fluid, for example a mixture of nickel salt in water solution suitable to grow Ni shells. The mandrel 10 coated with the gold film 26 is located in the electroforming bath opposite to a positive electrode 17. Mandrel 10 as well as an additional electroforming sample 18 are connected with the negative electrode. Applying a voltage across the electrodes initiates the electrochemical process during which a nickel layer 25 is formed on the gold layer 26. As mentioned before the invention is not restricted to the use of these materials. Any suitable materials may be selected by the skilled person.

Simultaneously an electroforming sample 18 is grown by the same electrochemical process. This sample 18 is used to measure possible internal mechanical tensions building up through the electroforming process using suitable analyzing techniques. The process is then controlled such that these internal mechanical tensions can be minimized. The temperature of the electroforming bath is preferably between 40 °C and 70 °C.

Now follows release step f). The mirror 21, 22 consisting of the mirror body 25 and the reflective layer 26 is uniformly and carefully released from mandrel 10. During this process step partial sticking of layer 26 to the mandrel is carefully avoided which would result in unwanted internal mechanical tension. For insuring a uniform release the cleaning step c) is essential.

In Figure 4 the method steps of reflective layer deposition, electroforming and release are depicted in more detail. Figure 4a shows a portion of mandrel 10 on which the reflective (gold) layer 26 having a thickness of several ten to several hundred nanometers has been deposited. Figure 4b shows the subsequent grown mirror body or shell 25. The adhesion of the reflective layer 26 (for example, gold) to the mirror shell 25 (for example, nickel) is higher than the adhesion of the reflective layer to mandrel 10. Shell 25 and reflective layer 26 are then released together from the mandrel. As can be seen from Figure 4 the optical surface of reflection layer 26 is the surface which has formed the interface with the mandrel having a very high surface smoothness. Therefore the surface smoothness of the reflective layer 26 of the present invention is much better than that of a reflective layer obtained by deposition on a conventional mirror due to surface roughness caused by the deposition process.

The mirror or reflective element may be provided with a supporting structure as for example, a ring 23a as shown in Figures 2a and 2b. This supporting ring is particularly useful if the mirror shell 25 is thin compared to the reflector diameter. The supporting structure may be attached before or after the release step f) in Figure 3. Preferably the supporting structure attachment step is carried out under

For the supporting structure a material having a thermal expansion coefficient similar to that of the mirror shell is used. The deviation of the thermal expansion coefficient is preferably smaller than 1%, more preferably smaller than 0.1%. This avoids a building up of mechanical stresses in the mirror body causing unwanted geometrical distortions.

The present invention allows the production of high precision optical elements by an electroforming replication technique in which one or more objects are electroplated onto the precision surface of a mandrel (masterpiece) that is an exact negative of the required surface. The layer of the deposited metal forms an exact copy of the mandrel surface that is then separated from the produced optical element. During the production process the master can be coated with a variety of materials that are separated with the electroformed object during the release to form a monolithic structure that includes a reflective coating. The mandrel remains unchanged by the process and can then be reused so that the high cost of conventional polishing techniques is limited to the production of the mandrel and results in the production of low cost high precision mirrors. The process according to the invention is particularly advantageous for the production of optical elements which have a high curvature. This high curvature allows the production of compact telescopes. It is to be understood that the present invention is applicable to any desired data transmission carrier wavelength and that the expression 'optical' is not to be interpreted as restriction to the visible and infrared spectrum.

CLAIMS

1. A method of manufacturing a telescope mirror (21, 22) comprising the steps of:
 - (a) providing a mandrel (10) defining the geometry of the telescope mirror,
 - (b) depositing a reflective layer (26) on the mandrel surface,
 - (c) electroforming a mirror body (25) onto the reflective layer (26) by an electrochemical process,
 - (d) releasing the mirror body (25) with the reflective layer (26) from the mandrel (10),wherein the electroforming process and the release process are controlled such that the building up of internal mechanical tension within the mirror body is suppressed.
2. The method according to claim 1, wherein the internal mechanical tension is measured during the electroforming process using an additional electroforming sample (18) which is electroformed in parallel and/or an electronic stress measurement device.
3. The method according to claim 1 further including the step of cleaning the mandrel (10) between the method steps (a) and (b).
4. The method according to claim 1, wherein the step of depositing the reflective layer (26) is carried out in a vacuum or electrochemical environment.
5. The method according to claim 1, wherein method step (d) is carried in clean room conditions.
6. The method according to claim 1, wherein the mirror body (25) is electroformed of Ni or Ni-alloy materials.

7. The method according to claim 1, wherein the electroforming step is carried out using an electrochemical liquid having a temperature of between 40 °C and 70 °C.
8. The method according to claim 1, wherein a supporting structure (23) is attached to the mirror body (25).
9. The method according to claim 8, wherein the supporting structure (23) is attached to the mirror body before releasing the latter from the mandrel.
10. The method according to claim 8, wherein the supporting structure (23) is attached to the mirror body after releasing the latter from the mandrel.
11. The method according to claim 8, wherein the supporting structure attaching step is carried out under temperature conditions similar to the operating temperature of the telescope mirror.
12. The method according to claim 1, wherein mandrels made of glass, zerodur, Polymethylmetacrylat (PMMA), composite material or metal are provided.
13. The method according to claim 1, wherein pure gold is used as material of the reflective layer (26) in method step (b).
14. A transceiver device (20) for high bandwidth free space optical data transmission comprising at least one reflector element (21, 22) having:
 - a reflector body (25) formed by an electrochemical replication technique using a mandrel (10) defining the geometry of the reflector element, and
 - a thin reflective layer (26) on the reflector body.
15. The transceiver according to claim 14, wherein the deviation of the reflector element from the design geometry is at any part of the reflector smaller than 50 μm , preferably smaller than 10 μm , more preferably smaller than 1 μm .

16. The transceiver according to claim 14, comprising a primary (21) and a secondary (22) mirror for concentrating an incoming electromagnetic wave into an optical fibre.
17. The transceiver according to claim 14, wherein the reflector element (21, 22) has a thickness in the range of 2 to 10 mm.
18. The transceiver according to claim 14, wherein the reflector element has a thickness of between 0,5 and 5 mm and being supported by a supporting structure (23).
19. The transceiver according to claim 14 wherein the reflector element has a thickness of between 10 μm and 500 μm and being supported by a supporting structure including actuators (23b) for adapting and correcting the geometry of the reflector element.
20. A telescope mirror (20) for high bandwidth free space optical data transmission comprising:
 - a mirror body (25) formed by an electrochemical replication process using a mandrel (10) defining a geometry of telescope mirror,
 - an optical reflective coating (26) on the mirror body.
21. The telescope mirror according to claim 20 further comprising a supporting structure (23) supporting said mirror body on the side opposite to the optical reflective coating, wherein the thermal expansion coefficient of said mirror body and said supporting structure are equal to one another within a deviation of 1%, preferably of 0.1%.
22. The telescope mirror according to claim 21, wherein the supporting structure is formed by an electroforming process.

23. The telescope mirror according to claim 21, wherein the material of the supporting structure is the same as the material of the mirror body.
24. The telescope mirror according to claim 20, wherein the supporting structure has a ring geometry (23a).
25. The telescope mirror according to claim 20, wherein the optical reflective coating consists of a thin high reflectivity metal film.
26. The use of reflector elements (21, 22) formed by an electrochemical replication technique using a mandrel (10) defining the geometry of the reflector element as optical mirrors for high bandwidth free space optical data transmission.
27. A method of high bandwidth free space optical data transmission from a transmitter station to a receiver station wherein at least one of the transmitter station and the receiver station comprises optical reflector elements (21, 22) formed by an electrochemical replication technique using a mandrel (10) which defines the geometry of the optical reflector element (21, 22).
28. The method according to claim 27, wherein the receiver station comprises optical reflector elements for concentrating a light beam having a diameter of between 10 and 100 cm into an optical fibre connection (31) having a diameter less than 150 μm with an efficiency of more than 80%, preferably more than 90%.
29. The method according to claim 27, wherein light having a wavelength of about 1550 nm is used for the data transmission.
30. The method according to claim 27, wherein the mandrel surface defines the surface smoothness of the reflective layer surface of the optical telescope.

Optical mirror elements for high bandwidth free space optical communication are produced by an electroforming replication technique. Onto the precision surface of a mandrel that is a negative of the required optical surface a layer of metal is deposited forming an exact copy of the mandrel surface and is then separated to form the required optical element. During the production process the mandrel may be coated with a variety of materials that are then separated together with the electroformed optical element during the release step to form a monolithic structure that includes a reflective coating. The mandrel remains unchanged by the process and can then be re-used. The high cost of conventional polishing techniques is therefore limited to the production of the mandrel. The replication process results in the production of low cost optical elements suitable for high bandwidth free space optical data transmission.

10	mandrel/masterpiece
11	rotatable shaft
12	machining tool
13	polishing tool
14	cleaning chamber
15	Au source
16	electroforming facility
17	anode
18	electroforming sample
20	telescope
21	primary reflector
22	secondary reflector
23a	supporting ring
23b	actuator
23c	supporting mechanism
25	reflector/mirror body
26	reflective layer
29	aperture
30	optical fibre network
31	optical fibre terminal

- | | |
|-----|-------------------------|
| 10 | mandrel/masterpiece |
| 11 | rotatable shaft |
| 12 | machining tool |
| 13 | polishing tool |
| 14 | cleaning chamber |
| 15 | Au source |
| 16 | electroforming facility |
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| 18 | electroforming sample |
| 20 | telescope |
| 21 | primary reflector |
| 22 | secondary reflector |
| 23a | supporting ring |
| 23b | actuator |
| 23c | supporting mechanism |
| 25 | reflector/mirror body |
| 26 | reflective layer |
| 29 | aperture |
| 30 | optical fibre network |
| 31 | optical fibre terminal |

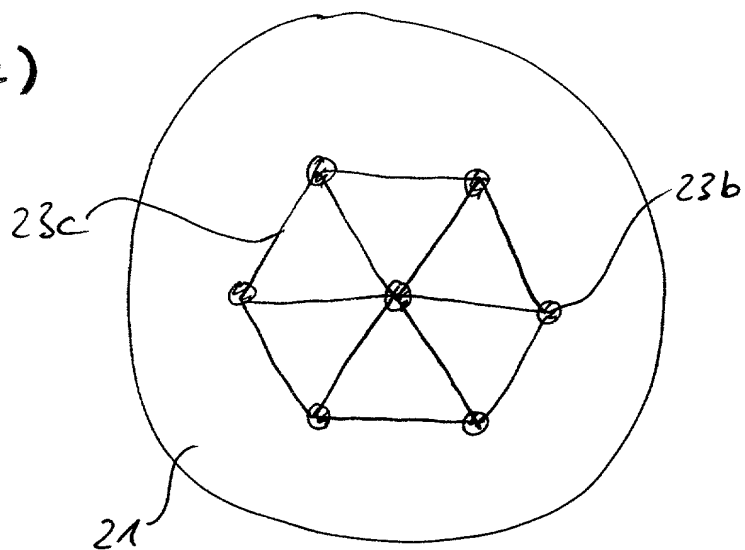
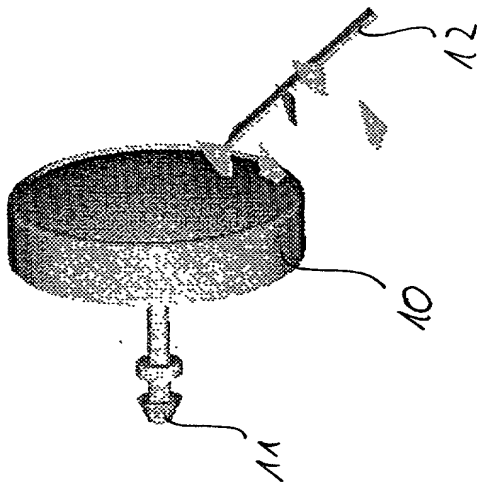
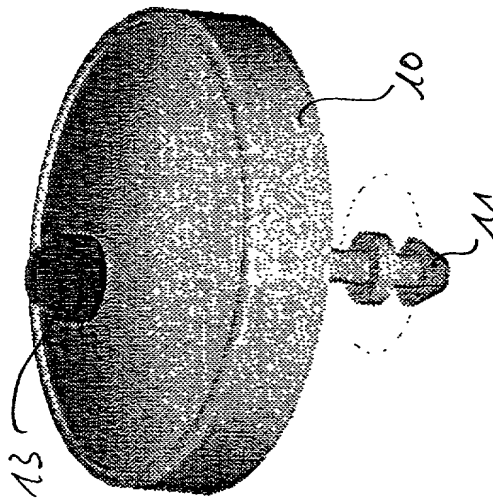
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Fig. 2

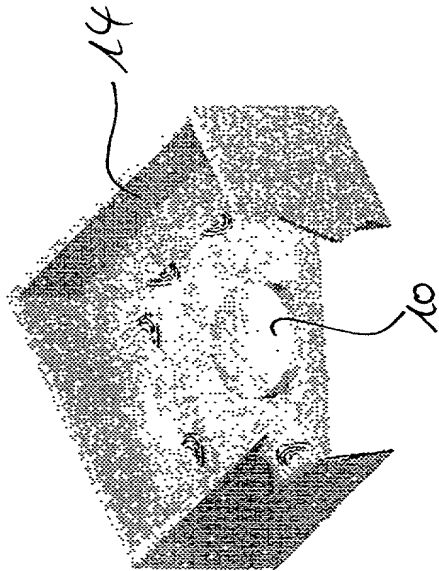
a) MASTER MACHINING



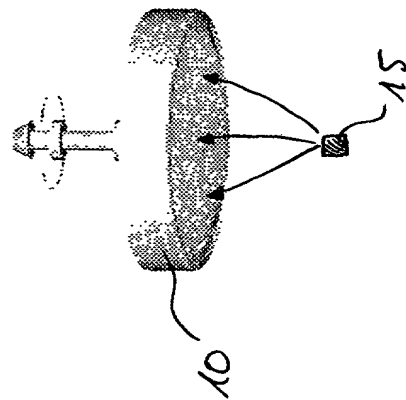
b) MASTER POLISHING



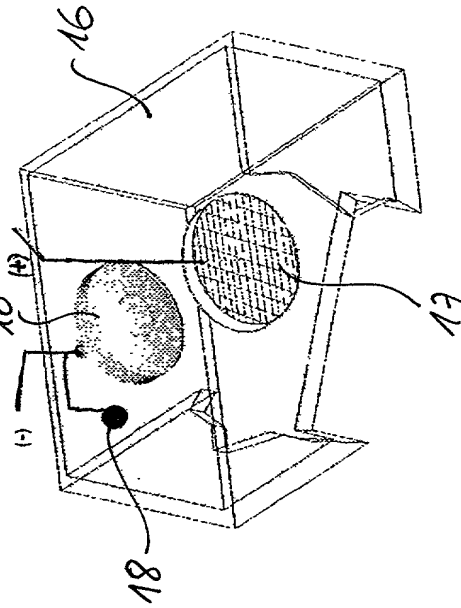
c) MASTER CLEANING



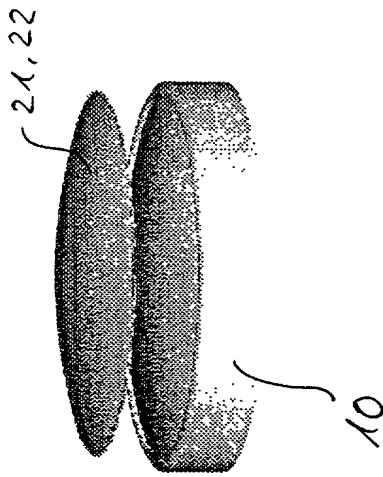
d) REFLECTIVE LAYER DEPOSITION



e) ELECTROFORMING



f) RELEASE



Q1



DECLARATION AND POWER OF ATTORNEY

DECLARATION:

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe, I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

TELESCOPE MIRROR FOR HIGH BANDWIDTH FREE SPACE OPTICAL DATA
TRANSMISSION

the specification of which (check only one item below):

X is attached hereto.

— was filed as United States Application
Serial No. _____ on _____
and identified as attorney docket B0843-991160.

X was filed as European application
Number 00109448.1 on May 3, 2000

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) on which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:			
Country (If PCT, indicate PCT)	Application Number	Date Filed	Priority Claimed (Yes/No)
EP	00109448.1	May 3, 2000	Yes

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. 120:					
U.S. APPLICATIONS			STATUS (check one)		
U.S. APPLICATION NUMBER	U.S. FILING DATE		PATENTED	PENDING	ABANDONED
PCT APPLICATIONS DESIGNATING THE U.S.					
PCT APPLICATION NO.	PCT FILING DATE	U.S. SERIAL NUMBERS ASSIGNED (if any)			

POWER OF ATTORNEY:

As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) with full power of substitution to act exclusively to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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Date:	
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Citizenship:	United Kingdom
Post Office Address:	Ridge Cottage/Glevering Hill, Wickham Market, Suffolk IP 13 ODG, United Kingdom

Demographic characteristics		Psychological characteristics		Social characteristics		Health characteristics		Economic characteristics	
Variable	Mean (SD)	Variable	Mean (SD)	Variable	Mean (SD)	Variable	Mean (SD)	Variable	Mean (SD)
Age	45.2 (12.5)	Depression	15.8 (10.2)	Marital status	5.1 (2.3)	Chronic illness	2.1 (1.5)	Income	1.2 (0.8)
Gender	1.1 (0.3)	Anxiety	12.5 (8.7)	Education	3.2 (1.1)	Current smoking	1.5 (0.7)	Unemployment	0.9 (0.4)
Ethnicity	1.5 (0.5)	Stress	18.3 (11.4)	Health insurance	2.8 (1.2)	Alcohol use	1.2 (0.6)	Healthcare access	1.1 (0.5)
Marital status	5.1 (2.3)	Life satisfaction	22.1 (9.8)	Health status	3.5 (1.8)	Physical activity	1.8 (0.9)	Healthcare costs	1.3 (0.6)
Education	3.2 (1.1)	Self-efficacy	25.4 (10.1)	Quality of life	28.7 (11.3)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)
Income	1.2 (0.8)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)
Unemployment	0.9 (0.4)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)
Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)
Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)
Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)
Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)
Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)
Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)
Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)
Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)
Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)
Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)
Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)
Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)
Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)
Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)
Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)
Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)
Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)
Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)
Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)
Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)
Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)
Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)
Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)
Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)
Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)
Healthcare utilization	1.4 (0.7)	Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization	1.4 (0.7)
Healthcare satisfaction	1.2 (0.5)	Healthcare costs	1.3 (0.6)	Healthcare access	1.1 (0.5)	Healthcare utilization			

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